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HERBICIDES ARE ESCALATING SEVERE PUBLIC HEALTH PROBLEMS BUT UNAVOIDABLE FOR FOOD SECURITY

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ABSTRACT

Herbicides are designed to kill unwanted vegetation and there has been a gradual increase in production and consumption of herbicides in agriculture to meet the rising food demands. But use of these toxic chemicals beyond the tolerance level have created imbalance in the system. Herbicides have undesirable effects on non-target organisms including humans directly or indirectly as their mode of action are not specific to one species. Although many of these chemicals are utilized or destroyed, much of these are released into the air, water and soil, representing a potential environmental hazard. Most of herbicides interfere with functioning of plant hormones or enzymes that do not have any direct counterpart in animals so these are less toxic to mammals compared with insecticides. Estimates of World Health Organization reported 3 million cases of pesticide poisoning every year and up to 220,000 deaths. Epidemiological studies and public health reports indicate that certain herbicides may be the reason for unintended, direct poisoning and various acute and chronic health concerns, especially in farmers, farm families, formulators, mixers and agricultural workers. Even very low levels of exposure during development phase of young children (foetal growth) may have adverse health effects. Children eat and drink more than adults in relation to their body weight and also inhale relatively more air so take relatively more residues.

KEYWORDS: Antidote, Herbicides, Public Health, Toxicity

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Review Article

INTRODUCTION

The term pesticide includes a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others. Herbicides has become a necessity in both intensive and conservation agriculture and are designed to kill unwanted vegetation and there has been a gradual increase in production and consumption of these to meet the rising food demands. In India, the pesticides are mainly used in agriculture and public health sector to prevent various pests and diseases that adversely affect the public.

The production of basic pesticides started with the manufacture of benzene hexachloride (BHC), followed by DDT in 1952. In 1958, India produced over 5000 metric tonnes of pesticides, especially insecticides like DDT and BHC (HCH). In the mid-nineties, the production was approximately 85,000 metric tones and about 145 pesticides were registered.

India is presently the second largest manufacturer of basic pesticides in Asia. It ranks 12th globally.

Herbicides are generally less toxic to mammals than insecticides as most critically interfere with plant hormones or enzymes and that do not have any direct effects on animals. People who regularly come in direct or indirect contact with pesticides must know the toxicity symptoms and preventative measures to reduce the pesticide toxicity effects. Various neurological health effects such as loss of coordination, memory loss, reduced visual ability, motor skills and speed of response to stimuli, altered general behavior, etc can be caused by pesticide exposure. These symptoms are often very subtle and may not be immediately recognized by the medical community as a clinical effect. Other possible health effects include asthma, allergies, hypersensitivity and pesticide exposure is also linked with cancer, hormone disruption, and problems with reproduction and feotal development. The use of toxic pesticides to manage pest problems has become a common practice around the world.. Pesticide use is common in crop fields and at domestic level and these contaminate our environment (air, soil and water) and food Pesticides can cause a wide range of human health hazards, ranging from short-term impacts such as headaches, stinging eyes, rashes, blisters, blindness, nausea, dizziness, diarrhea and nausea to chronic impacts like cancer, birth defects, reproductive harm, immunotoxicity and endocrine disruption[(1)]. Otherwise considered safe and protected area but to the surprise of Government of Australia, various herbicides were detected in the Great Barrier Reef catchment area namely ametryn, atrazine (and degradation products), bromacil, 2,4-D, diuron, hexazinone, MCPA, metolachlor, simazine, tebuthiuron, paraquat and glyphosate to toxic levels[(2,3)].

Production and Consumption of Herbicides

Globally, about 2 million tonnes of pesticides are consumed per year. Europe and USA alone consumed 45 and 25% of total pesticide consumption, respectively, and only 25% are consumed in rest of the world. India's share is just 3.75%. Korea and Japan use 6.6 and 12.0 kg/ha of pesticides, respectively, as against 0.5 kg/ha in India. While discussing the worldwide consumption of pesticides, herbicide share is 47.5%, 29.5 % is the share of insecticides, 17.5 % is that of fungicides, and others account for 5.5 % only (Figure 2). In India (Figure 1), 80% of pesticides are consumed in the form of insecticides, 15% share is of herbicides, 2% are consumed in the form of fungicides and less than 3% are others[(4)]. Currently, the consumption of pesticide is showing a slight declining trend, probably due to shift of farmers toward biopesticides, natural plant sources and other alternative methods. Despite such a large consumption of pesticides, it is estimated that crop losses vary between 10–30% due to pests alone. In monetary terms, these losses amount to Rs. 290,000 million per year.

Herbicides and Public Health

Herbicides are generally less toxic to humans as the plants and human beings are physiologically different (Table 1). Herbicides can cause dermal irritation and inhalation of spray mist can cause coughing, dizziness and a burning sensation in the nasal passages and chest as they are often strong acids, amines, esters and phenols. Vomiting, a burning sensation in the stomach and diarrhea can be caused on ingestion of a herbicide. Some herbicides cause health effects ranging from skin rashes to death (Table 2). Consumption of contaminated foods and crops with residues of herbicides causes serious diseases in humans. Bioaccumulation (biomagnification) of some herbicide takes place in food chain. Persistent pollutants like herbicides favour growth of cyanobacteria harmful algal bloom which produce toxin potent enough for human death[(5)]. Pesticides can enter the human body through inhalation of aerial sprays, ingestion, by dermal penetration through the skin, intentional or unintentional direct consumption, improper application or food consumption prior to the labeled pre-harvest interval, etc. Those who work with agricultural pesticides are the most at risk if they are not

properly dressed or if there are broken and leaking equipment. Under some conditions, certain herbicides can be transported via leaching or surface runoff to contaminate groundwater or distant surface water sources. Intense storm events (particularly immediately after application) and soils with less capacity to adsorb the herbicides promote herbicide transport and the persistence (resistance to degradation) and high water solubility of a herbicide are responsible for increased transport[6]. Exposure to insecticides within the home and herbicides outside is associated with blood cancers in children[7]. Both insecticides and herbicides significantly increased the risk of Parkinson's disease. Agent Orange, a 50:50 mixture of 2,4,5-T and 2,4-D, is associated (Table 3) with bad health and genetic effects in Malaya and Vietnam[8,9]. A number of pesticides including dibromochlorophane and 2,4-D have been linked with impaired fertility in males[10]. The risk of Parkinson's disease has been shown to increase with occupational exposure to herbicides and pesticides[11]. Phenoxy herbicides are commonly contaminated with dioxins (TCDD), it is reported that the contamination with dioxins resulted in some increase in cancer risk after occupational exposure to these herbicides[12]. Herbicide 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) itself is of only moderate toxicity, however during the manufacturing process, this chemical get contaminated with trace amounts of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). TCDD is highly toxic to humans. Proper temperature control during manufacturing of 2,4,5-T can help in minimizing the TCDD level to about 0.005 ppm. Earlier, when the TCDD risk was not well known, the manufacturing facilities lacked proper temperature controls. Individual batches tested later were found to have about 60 ppm of TCDD. To assess the developmental and reproductive safety of glyphosate, an analysis of the available literature was conducted. Triazine exposure has been implicated in a likely relationship to increase risk of breast cancer, although a causal relationship remains unclear[13].

Epidemiological Studies

Epidemiological studies and reports on mechanisms of action related to likely developmental and reproductive effects of glyphosate have also been thoroughly studied and critically reviewed by many workers. Assessment of this database found no reliable effects of glyphosate exposure on reproductive health or developing offsprings. In addition no credible mechanisms of action for such effects were elucidated. Even though toxicity was observed in studies that used glyphosate formulations but data stoutly suggested that effects were owing to surfactants present in the formulations and not the direct result of glyphosate contact. The studied literature showed no evidence connecting glyphosate exposure to adverse developmental or reproductive effects at realistic exposure concentrations[14].

Epidemiological studies showed association of an array of cancers with all the main functional classes of pesticides (namely herbicides, insecticides, fungicides, fumigants) and chemical classes including phenoxy acid and triazine herbicides like simazine with prostate cancer, butylate with prostate cancer, dicamba with colon cancer, imazethapyr with colon and bladder cancers, pendimethalin with rectal cancer, trifluralin with colon cancer, atrazine with bone cancer and leukaemia, metolachlor with bone cancer, lung cancer and leukaemia, simazine with prostate cancer, glyphosate with non-Hodgkin’s lymphoma and cancer of breast, rectal, and brain[15]. Exposures to endocrine disrupting chemicals during early life stages will leave permanent and irreversible effects. Children are born carrying a significant load of pesticides, including organochlorines and organophosphates[16] and breast milk commonly carries loads of pesticide residues including atrazine, chlorpyrifos and malathion[17] Although clear-cut cause-and-effect relationships are often elusive because of long time gap between first exposure and presentation of clear clinical symptoms; where as epidemiological studies can be done to ascertain the risk associated with use of herbicides and other pesticides. Kurenbach et al[18] reported that exposures of Escherichia coli and Salmonella enterica serovar Typhimurium to sub-lethal doses of

commercial formulations of three herbicides namely dicamba, 2,4-dichlorophenoxyacetic acid (2,4-D) and glyphosate were found to induce a effective changed response to antibiotics, suggesting their compromise in therapeutic effects of antibiotics against microbes.

Although triazines are effective and inexpensive compounds applied as herbicides. Human exposure to triazines has been associated with carcinogenicity and endocrine disruption, but these effects are still debatable[19]. The chlorine group of the triazine structure is replaced with free-SH group of glutathione, with terminal peptide cleaved, and the cysteine moiety is N-acetylated. The mercapturate residues (mercapturic acid) and the dealkylation metabolites are consequently excreted in the urine[20]. Triazines can cause serious skin problems because of toxicity and also observed in some cases about reduced body weight.[21]. Potent and toxic paraquat causes aggressive tissue damage in the lungs, kidneys and liver. The major target organ of paraquat poisoning is the lung, which consists of the most lethal and the least treatable manifestation of toxicity. Reactive oxygen species (ROS) play a crucial role in paraquat induced pulmonary injury, characterized by edema hemorrhage and hypoxemia, as well as infiltration of inflammatory cells[22]. Some cancers have been associated with specific exposures, and may be increased in subgroups of agricultural workers. NHL and phenoxyacetic acid herbicides (e.g. 2,4 D) have shown the strongest association[23], but the finding has not been consistent[24,25].

The Ill Effects of Herbicides on Human Health Can Be Minimized By Following the Points Given Below

- Follow the Integrated Pest Management (IPM) strategy.
- Always follow the precautionary measures written on the label.
- Take steps to minimize your exposure, even when using low toxicity pesticides.
- Wear long-sleeved shirt, long trousers, gloves, and proper footwear for minimum dermal protection.
- Respiratory protection is especially important when there is risk of inhalation of pesticide powders, dusts, gases, vapours, or small spray droplets.
- Store pesticides only in their original containers, and keep the original label attached to the container to avoid accidental oral exposure.
- While pouring, keep the container below eye level to evade splashing or spilling chemicals on your face or protective clothing.

Lethality and Antidotes

We should all, for the sake of our future generations, need to make our food, air, water, and soil free from deadly chemicals. The factual resolution to our pest and weed problems lies in non-toxic and cultural methods of agriculture and not in pulling the pesticide trigger. Pressure to produce more food for more ever increasing population will not ease this pressure to hold back the use of agro chemicals herbicides. Sustainable methods of pest control naturally and organically grown foods and are key to our families' health and the health of our surroundings. A acceptable way to document toxicity is by oral LD_{50} values (Table 4). LD_{50} is the amount of chemical required to provide a "lethal dose" to 50% of the test population. LD_{50} is measured in mg of chemical administered per kg of body weight. An oral LD_{50} of 500 means that 500 mg of chemical was needed to obtain lethality in one kg subject. The lower the LD_{50} value, the less chemical that is required to reach lethality. A chemical with an LD_{50} of 10 mg/kg is more acutely toxic than one with an LD_{50} of 100

mg/kg. The LD_{50} Value of some herbicides are given in table 4. Pesticides that are classified as highly toxic (Toxicity Category I) on the basis of either oral, dermal, or inhalation toxicity must have the signal words DANGER and POISON printed in red with a skull and crossbones symbol prominently displayed on the front panel of the package label. The acute (single dosage) oral LD_{50} for pesticide products in this group ranges from a trace amount to 50 mg/kg. For illustration, exposure of a few drops of a material taken orally could be fatal to a 150-pound person. Some pesticide display just the word **DANGER**, which tells nothing about the acute toxicity but the product can cause rigorous eye damage or skin irritation.

Pesticide products considered fairly toxic (Toxicity Category II) must have the signal word **WARNING**. In this category, the acute oral LD_{50} ranges from 50 to 500 mg/kg. A teaspoon to an ounce of this material is fatal to a 150-pound person. Pesticide classified as either slightly toxic or relatively nontoxic (Toxicity Categories III and IV) are required to have the signal word **CAUTION** on the pesticide label. Acute oral LD_{50}values in this group are greater than 500 mg/kg. An ounce or more of this material could be fatal to a 150-pound person. Antidotes may play an important role in the treatment of poisoning (Table 5). Fine supportive care and abolition techniques may restore a poisoned patient to good health and calm down his or her body functions. Appropriate use of antidotes and other agents may greatly augment elimination and neutralize the toxic actions of the poison. In certain situations they may appreciably reduce the medical resources otherwise needed to treat a patient, shorten the period of therapy and even save a patient from death. Hence, antidotes will, for sure reduce the overall burden on the health service of managing cases of poisoning. In far off areas remote from good hospital services and particularly in developing countries that lack adequate facilities for supportive care, antidotes may be even more indispensable in the treatment of poisoning. Poison information centres (PIC) play a key role in the accomplishment of a national antidote programme. In general, they are in the distinctive position of having an overall picture of local poisoning incidents that will facilitate them to identify the need for specific antidotes in the country as a whole, as well as in particular areas[(26)]. It is therefore, a principal task of these centres to draw attention to the need for making suitable antidotes available. They should review and evaluate the relevant literature, keep authorities informed, and facilitate any necessary activities. Good first-aid measures and the proper use of antidotes may be not only lifesaving but also inexpensively sound. Although antidotes are sometimes expensive, their use may prevent death, and prolonged hospitalization. The benefits thus prevail over the costs. International agencies may be cooperative in enabling some countries to obtain the antidotes they need[(27,28)].

CONCLUSIONS

Individual are exposed to toxic chemicals, usually in very small, sub toxic doses, through eco-systems and food infectivity. Some instances although not rare, peoples are subjected to massive and deadly results, exposure through a chemical calamity or deliberate poisoning. Intensity of exposure may also result in various acute and chronic lethal effects. These effects without a doubt lie in the public health sphere predominantly in cases of chemical contamination of the environment that may result in exposure of an innocent people. Although absorbed chemical is in small quantities yet they do not induce any pathological signs until toxic concentration are reached in the tissues of exposed persons.

According to WHO's (World Health Organizations) definition of health and its goal of "health for all ", globally all human beings should have access to significant information on how to prevent and deal with poisoning. Poison information centre's provide such information and are an essential part of a country's capacity for ensuring the safety of chemical substances. Moreover, the United Nations, through its Conference on Environment and Development, has called

upon all countries to promote the establishment of poison information centre's with related chemical and analytical facilities to ensure prompt and adequate diagnosis and treatment of poisoning, including networks of centers for chemical emergency response. The pharmaceutical and chemical industries **(PCI)** have an important part to play in the research and development activities as far as first aid treatment and emergency response is considered. The **PCI** could explore ways and means of ensuring the manufacture and distribution of antidotes, which would not normally be made available if commercial criteria alone prevailed. Those industries that use or manufacture toxic chemicals could ensure the availability of, or ready accessibility to, appropriate antidotes at sites used by their workers and at nearby hospitals. Industrialized nations and marketable enterprise should ensure the proper training of their health human resources in the emergency use of antidotes. Importers and distributors of toxic chemicals should ensure the availability of precise and effective antidotes for the substances in which they do business.

Government should make sincere efforts aimed at registering and controlling distribution of pesticides and banning hazardous ones. This could be achieved through stricter enforcement of existing regulation and monitoring policies and it should make newer, less toxic chemical pesticide more readily available to the farmers in ready-to-use packages. Finally, pesticide manufacturers should be instructed and compelled to exhibit pesticide instructions and warning labels in the language commonly understood by the farmers and other end users, and also to package products in containers that are not attractive for subsequent re-use according to the International Code of Conduct on the Distribution and Use of Pesticides. To sum up, based on limited knowledge with direct and indirect and/or inferential information on pesticides, there is a certain ambiguity of a situation in which people are undergoing life-long exposure. Therefore, there is every reason to properly educate farmers and general public for judicious use of pesticides. Other alternatives such as use of biotechnology, use of biopesticides, and use of pesticides obtained from natural products should be encouraged.

CONFLICTS OF INTEREST: None.

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APPENDICES

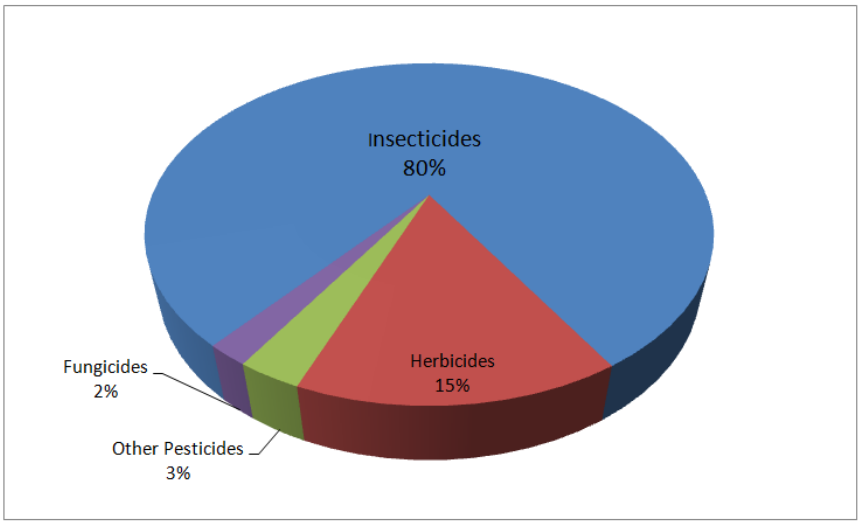

Figure 1: Consumption of Pesticides in the Indian Scenario

A De et al., Targeted Delivery of Pesticides Using Biodegradable Polymeric Nanoparticles, Springer Briefs in Molecular

Science, DOI: 10.1007/978-81-322-1689-6_2, The Author(s) 2014

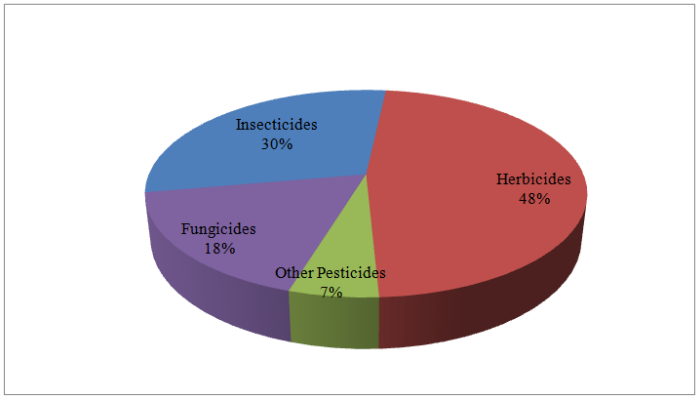

Figure 2: Worldwide Consumption of Pesticides

A De et al., Targeted Delivery of Pesticides Using Biodegradable Polymeric Nanoparticles, Springer Briefs in Molecular

Science, DOI: 10.1007/978-81-322-1689-6_2, The Author(s) 2014

Table 1: Herbicides Group/ Classification

Herbicide Chemical Group	Mode of Action	Activity Site	Persistence in Soil	Acute Mammalian Toxicity	Examples
Aliphatics	Systemic	interferes with growth (grasses)	1-3 months	low	dalapon, TCA
Bipyridyliums	Contact (foliar application)	destroys cell membranes	deactivated immediately by soil	moderate to high	diquat, paraquat
Benzoic acids	Systemic	disrupts plant hormone balance and affects growth	2-3 months	low	dicamba, chloramben
Carbamates	Systemic	inhibits cell division or photosynthesis	≤ 1 month	low	asulam, barban, chloramben
Phenoxys	Systemic	disrupts plant hormone balance and affects growth	≤ 1 month	low to high	2, 4 D, dichlorprop, mecoprop, MCPA
Thiocarbamates	Systemic	disrupts plant hormone distribution, inhibits cell division	1-8 weeks	low	butylate, EPTC, triallate, vernolate
Triazines	Translocat-ed to leaves	interferes with photosynthesis	few weeks to 1 year	low to moderate	atrazine, metribuzin, prometryne, simizine, terbutryn
Uracils	Systemic	inhibits photosynthesis	6 months to several years	low	bromacil, terbacil
Ureas	Systemic	inhibits photosynthesis	few months to > 1 year	low	diuron, linuron, chloroxuron, tebuthiuron, chlorbromuron

Table 2: Toxicity Categories for Pesticides as Classified by the Environment Protection Agency of the USA

Toxicity Indicators	Toxicity Categories			
	I	II	III	IV
Colour Code	**Red label**	**Yellow label**	**Blue label**	**Green label**
Signal word	DANGER (Poison)	WARNING	CAUTION	CAUTION
Toxicity class	Extremely hazardous	Highly hazardous	Moderately hazardous	Slightly hazardous
Oral LD_{50} (mg/kg)	50 or lower	50-500	500-5000	5000 +
Inhalation LC_{50}				
1. Dust or mist (mg/l)	20 or lower	2.0-20	20-200	200 +
2. Gas or vapours (ppm)	200 or lower	200-2000	2000-20000	20000+

Table 2: Contd.,				
Dermal LD_{50} (mg/kg)	200 or lower	200-2000	2000-20000	20000+
Eye effect	Irreversible corneal opacity at7 days	Corneal opacity or reversible within 7 days, irritation for 7 days	No corneal opacity, irritation gone within7 days	No irritation
Skin irritation	Severe irritation or damage at 72 hours	Moderate irritation at72 hours	Mild irritation at 72 hours	No irritation at 72 hours
Examples of herbicides	-	anilofos, paraquat, 2, 4-D	pendimethalin, isoproturon, atrazine, metribuzin, alachlor, trifluralin, diuron, clodinafop, glyphosate	oxyflourfen, pretilachlor, azimsulfuron, metsulfuron, oxadiargyl, imazethapyr, pinoxaden, sulfosulfuron,

Table 3: Signs and Symptoms of Acute Exposure for Several Herbicides Active Ingredient

Active Ingredient	Brand Name	Signs & Symptoms
Dichlorophenoxy acetic	2,4-D, Barrage	Irritating to skin, mucous membranes. Vomiting, headache, diarrhea, confusion. Bizarre or aggressive behavior. Muscle weakness in occupationally exposed individuals.
Acetochlor	Harness, Surpass	Irritating to skin, eyes, respiratory tract.
Atrazine	Aatrex, Atranex	Irritating to skin, eyes, respiratory tract. Abdominal pain, diarrhea, vomiting. Eye irritation, irritation of mucous membranes, skin reactions.
Dicamba	Banvel, Metambane	Irritating to skin, respiratory tract. Loss of appetite (anorexia), vomiting, muscle weakness, slowed heart rate, shortness of breath. Central nervous system effects.
Glyphosate	Rodeo, Roundup	Irritating to skin, eyes, respiratory tract.
Mecoprop	Kilporp, MCPP	Irritating to skin, mucous membranes. Vomiting, headache, diarrhea, confusion. Bizarre or aggressive behavior. Muscle weakness in occupationally exposed individuals.
Metolachlor	Bicep, Dual	Irritating to skin, eyes
Paraquat	Gramoxone	Burning in mouth, throat, chest, upper abdomen. Diarrhea. Giddiness, headache, fever, lethargy. Dry, cracked hands, ulceration of skin. abdomen. Diarrhea. Giddiness, headache, fever, lethargy. Dry, cracked hands, ulceration of skin.
Pendimethalin	Prowl, Stomp	Irritating to skin, eyes, respiratory tract
Propanil	Propanex, Stampede	Irritating to skin, eyes, respiratory tract

Table 4: LD_{50} and Corresponding Herbicides

Herbicide	LD_{50}
Paraquat (Gramoxone)	~100
Triclopyr	630
2,4-D	666
Pendimethalin (Prowl)	1050
Atrazine	3090
Glyphosate (Roundup)	4900
Imazaquin (Image)	>5000
Table salt	3000

Table 5: Herbicides Antidotes For Human Beings

Herbicide	Antidote
Anilophos (Arozin, Libra, Aniloguard)	**Atropine**: 2-4 mg l/V as a test dose. If no effect, double dose may be given every 10 minutes till atropinization. Maintain upto 24-48 hrs. **2-PAM:** 1-2 g intravenous as 5 % solution in dextrose to be given in 5-7 min or 150 ml of Anilophos Padigard etc. Saline drip every 30 min. if required it may be repeated every hour if the muscle weakness and fasiculation persists. To be continued every 6-8 hours for 1-2 days or 5 % solution as infusion @ 1/2g/hr. **2-PAMCL:** Dose same as above. Gastric lavage with 5 % sodium bicarbonate.
2,4-D	**Ingestion:** Gastric lavage with activated charcoal slurry. For muscle and cardiac irritability give Lidocaine 50-100 mg itravenous, followed by 1-4 mg/min as needed. Alkalize urine by sodium bicarbonate 10-15 g daily intravenously.
Glyphosate (Roundup)	**Ingestion:** Immediately dilute by swallowing milk or water.
Isoproturon (Arelon, Delron, Milron etc.)	Flush eyes with soap. Wash skin with soap and water.
Paraquat (Grammaxone)	Induce vomiting unless unconscious. Give gastric lavage with one litre of 30 % aqueous suspension with Fuller's earth together with sodium sulphate. Repeat admonistration until Fuller's earth is seen in stool.

From "Package of practices for crops of Punjab - Kharif 2016"Punjab Agricultural University. pp 179